

Video Article

Expired CO₂ Measurement in Intubated or Spontaneously Breathing Patients from the Emergency Department

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Abstract

Carbon dioxide (CO₂) along with oxygen (O₂) share the role of being the most important gases in the human body. The measuring of expired CO₂ at the mouth has solicited growing clinical interest among physicians in the emergency department for various indications: (1) surveillance et monitoring of the intubated patient; (2) verification of the correct positioning of an endotracheal tube; (3) monitoring of a patient in cardiac arrest; (4) achieving normocapnia in intubated head trauma patients; (5) monitoring ventilation during procedural sedation. The video allows physicians to familiarize themselves with the use of capnography and the text offers a review of the theory and principals involved. In particular, the importance of CO₂ for the organism, the relevance of measuring expired CO₂, the differences between arterial and expired CO₂, the material used in capnography with their artifacts and traps, will be reviewed. Since the main reluctance in the use of expired CO₂ measurement is due to lack of correct knowledge concerning the physiopathology of CO₂ by the physician, we hope that this explanation and the video sequences accompanying will help resolve this limitation.

Protocol

Material Used in Capnography

One of the obstacles to the utilization of expired CO₂ monitoring resides in the disparity of the material used by emergency physicians. To clarify this situation, it is important to distinguish whether the patient is artificially ventilated or breathing spontaneously. As for the rest, the different techniques used for analysis no longer have an implication on clinical results and efficiency.

This statement stands in the case of the traditional distinction between sidestream and mainstream capnography. These two techniques measure CO₂ using infrared waves; the sidestream system uses an aspiration pump to transport CO₂ from the mouth to the detector situated in the monitor, while the mainstream system measures CO₂ directly in a small chamber situated at the mouth of the patient and connected to the monitor by a cable. Traditionally, the sidestream system is used for patients breathing spontaneously as the system is lighter, and the mainstream system, a little bulkier, is connected directly to the endotracheal tube in intubated patients. Technological advances in the last years have fundamentally reduced the differences between mainstream and sidestream systems. New technology is pointing towards the microstream system, which is a sort of 'enhanced sidestream system' in which CO₂ travels along a thin tube before reaching the chamber where the detector is located, allowing a smaller transition period between the mouth and the detection chamber and thus a capnography curve that is almost synchronized with the passage of air at the mouth. So, let us have a look at what distinguishes the choice of material, as explained in the second half of the video sequence:

- If the physician wishes to monitor a patient in spontaneous ventilation so as to precocely detect apnea (during procedural sedation, or after medical intoxication), then only the form of the curve is essential, the actual value of ET-CO₂ being of less importance. In this case, he physician can choose between nasal prongs or a capnomask combining oxygen administration and CO₂ aspiration, or a thin CO₂ aspiration tube that can be placed under a classical mask.
- If the physician wishes to precisely analyse ET-CO₂ in order to adapt the parameters on a respirator, to verify the correct positioning of an endotracheal tube, or to evaluate the prognosis during cardiac arrest, he must use the material than can be adapted for use with an endotracheal tube (always placed behind the filter so as secretions from the patient do not block the tube).

The Capnography Curve

A typical capnography curve during three expirations is given in Figure 1. The curve regains the x-axis (0 value) at each inspiration, as there is virtually no CO₂ in inspired air.

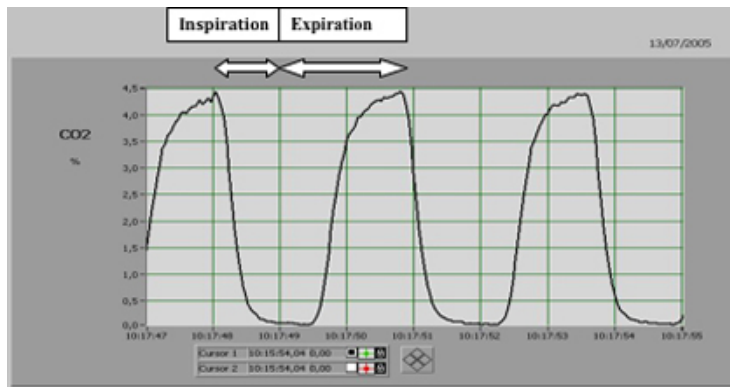


Figure 1: alternance inspiration-expiration

Differences Between PaCO₂ and ETCO₂

It would be eutopic to believe that non-invasive monitoring of expired CO₂ can replace in all circumstances the need for arterial blood gas (ABG) measures, considered to be the gold standard for the measurement of PaCO₂. All depends on the indications for the measurement of expired CO₂ and the patient's cardio-respiratory condition. If the indication is the monitoring of respiratory activity to prevent hypoventilation and apnea during sedation, a simple analysis of the curve is sufficient, whatever the value of ETCO₂. On the other hand, if the indication is to monitor the adequate ventilation of a head trauma patient with no history of cardio-respiratory disorders, we can expect the ETCO₂ value to be close to the PaO₂ value, though the necessity of a precise PaCO₂ value imposes at least one ABG sample, which also allows us to confirm that indeed ETCO₂ is close to PaCO₂ in the present case.

Finally, if we are faced with the case of a patient that is intubated and ventilated due to respiratory distress, ETCO₂ values will evidently not be a good approximation of PaCO₂. The reason is simple; as soon as there is a disturbance in ventilation-perfusion ratios, regardless of what the cardio-pulmonary disorder present is, an obstacle to the correct elimination of CO₂ by the lungs is created. As a result, CO₂ accumulates in the blood, and naso-buccal elimination is reduced, creating a PaCO₂ - ETCO₂ gradient. In this circumstance, it is crucial to know the value of PaCO₂ before any interpretation of the ETCO₂ value.

The first part of the video sequencedescribes the procedure to be followed for interpreting the difference between PaCO₂ and ETCO₂. We see that the measure of ETCO₂ is obtained immediately and in a non-invasive manner, but at this stage cannot allow the adaptation of the respirator's parameters. This implies having to measure the PaCO₂ that can then be compared with the ETCO₂. The PaCO₂ value remains the referral value for the appreciation of patient ventilation.

- If PaCO₂ measured is higher than the desired value, for example 60mmHg instead of 40mmHg, this signifies that the patient is hypoventilated. The respirator's parameters can then be adapted; either the respiratory rate or the tidal volume can be increased in order to increase the ventilation and thus decrease PaCO₂. The objective consists in reducing the ETCO₂ by 20mmHg, regardless of what the initial ETCO₂ value. For example, it can be possible that the ETCO₂ value is 50mmHg when the PaCO₂ is measured at 60mmHg, due to a PaCO₂ -ETCO₂ gradient created by the presence of a cardio-respiratory disease. When the adaptation of the respirator's parameters allows the ETCO₂ to drop from 50mmHg to 30mmHg, we can safely suppose that the patient is adequately ventilated with a PaCO₂ value having dropped from 60mmHg to 40mmHg.
- Inversely, if the PaCO₂ is lower than the target value, the patient is hyperventilated and consequently respiratory rate or tidal volume must be reduced to attain the target value. If PaCO₂ is 20 mmHg lower than the targeted value, one has to increase the ETCO₂ by 20mmHg through modification of the respirator's parameters.

Artifacts and Traps in Capnography.

If the technology for CO₂ measurement has become reliable in terms of precision, reproducibility, response time and curve quality, it still presents, as for any monitored parameter, certain limits:

- The first limitation is due to lack of correct knowledge concerning the physiopathology of CO₂ by the physician, who then is reluctant to use the technique. We hope that this explanation and the video sequences accompanying will help resolve this limitation.
- In the case of the spontaneously breathing patient, the adjunction of oxygenotherapy via the mask will dilute the expired CO₂, which will significantly modify the capnogram and the ETCO₂ will drop. The video sequence demonstrates this phenomenon.
- If one wishes to monitor for hypoventilation, or an apnea event, during procedural sedation, we expect ETCO₂, in correlation to PaCO₂, to increase in parallel to hypoventilation of the patient. Paradoxally, a hypoventilation event in a patient breathing spontaneously is translated by a drop in ETCO₂, because the patient is then only breathing with a very small tidal volume, which essentially corresponds to the dead volume of the tracheo-bronchial space; and as we know, this space does not participate in gaseous exchange and thus contains very little CO₂.
- During mechanical ventilation, the pitfall is that one forgets that ETCO₂ does not necessarily reflect PaCO₂ (see previous chapter).

Discussion

Importance of CO₂ for the Organism

Before exploring expired CO₂ monitoring, it is essential to put into perspective the general role played by CO₂ in the human body. Produced at a rate of approximately 200 ml per minute, CO₂ is not just a wasted by-product of cellular metabolism. If our medullar chemoreceptors have the role of maintaining the arterial CO₂ partial pressure (PaCO₂) at 40mmHg, it is because CO₂ has other functions in the organism that the emergency physician encounters on a daily basis:

- CO₂ constitutes an incredible reserve as a tampon to the continued production of acid by the organism, and thus allows the maintenance of an adequate pH.
- CO₂ values correlate reliably with the patient's ventilation, and its measure is crucial in order to affirm hypo- or hyperventilation of the patient.
- CO₂ plays an important role in the regulation of cerebral perfusion, hypercapnia resulting in vasodilatation and consequently cerebral edema, and inversely hypocapnia provoking vasoconstriction and the risk of ischemia.
- CO₂ values vary in complement to changes in O₂ values: the hypocapnia subsequent to hyperventilation constitutes the organism's first reflex reaction to hypoxia when faced with respiratory disease or increase in altitude.

What Expired CO₂ Represents

The CO₂ value as measured at the mouth reflects three fundamental processes: (1) tissular production of CO₂, (2) its transport in the venous system to the pulmonary arteries, and (3) its elimination by the lungs. In emergency medicine, the principal indications for the use of expired CO₂ measurement involves the third process and, more precisely, provides a method of evaluation of the patient's ventilation. An exception is during cardiac arrest, where the measuring of expired CO₂ also reflects the transport of CO₂ in the circulatory system, to the extent that a continuously low value of ETCO₂ after 20 minutes of correctly-conducted reanimation conveys the (probably) irreparable absence of blood circulation

Relevance of Measuring Expired CO₂

End tidal CO₂ (ETCO₂) values correlate with arterial CO₂ (PaCO₂) values, and thus measuring ETCO₂ reduces the need for repeated, sometimes difficult and not forgetting painful, arterial blood gas sampling. EtCO₂ is typically 3mmHg less than PaCO₂. This correlation is only valid if the patient carries no pulmonary disease or defect. For all situations where the ventilation - perfusion ratio is varied, a gradient between the PaCO₂ and the ETCO₂, and thus ETCO₂ measurement has to be combined with ABG sampling in order to obtain the real value of the PaCO₂.

Disclosures

No conflicts of interest declared.

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